3A94-16

1992 YUKON RIVER BORDER SONAR PROGRESS REPORT

By

Daniel C. Huttunen

and

Paul A. Skvorc, II

Regional Information Report[1] No. 3A94-16

Alaska Department of Fish and Game
Commercial Fisheries Management and Development Division
333 Raspberry Road
Anchorage, Alaska

April 1994

---

[1]The Regional Information Report Series was established in 1987 to provide an information access system for all unpublished divisional reports. These reports frequently serve diverse ad hoc informational purposes or archive basic uninterpreted data. To accommodate timely reporting of recently collected information, reports in this series undergo only limited internal review and may contain preliminary data; this information may be subsequently finalized and published in the formal literature. Consequently, these reports should not be cited without prior approval of the author or the Commercial Fisheries Management and Development Division.

AUTHORS

Daniel C. Huttunen is statewide riverine and marine sonar research biologist for the Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Sonar and Technical Services Section, 333 Raspberry Road, Anchorage, AK 99518.

Paul A. Skvorc, II is the statewide sonar supervisor for the Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Sonar and Technical Services Section, 333 Raspberry Road, Anchorage, AK 99518.

ACKNOWLEDGEMENTS

Many people contributed to the acquisition of the data presented in this report. Contributing Alaska Department of Fish and Game staff included Dale Kohlmoos, and Janice Densham. Contributing U.S. Fish and Wildlife Service staff included Rod Simmons, Dave Daum, Judy Gordon, and Mitch Osborne. Sam Johnston of Hydroacoustic Technology Inc. provided technical support.

PROJECT SPONSORSHIP

This project was partially supported by US/Canada Yukon River funds through Cooperative Agreement Number NA26FP0125-01.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

Side-looking scientific fisheries split beam hydroacoustic equipment was deployed in the Yukon River at Eagle, Alaska from 20 July through 2 August, and from 6 through 22 September 1992 to collect baseline target strength and three-axis position data on migrating chinook and chum salmon. *In situ* target strength estimates of standard calibration spheres and free swimming fish were close to theoretical values. Gillnet test fishing catches at the site indicate that chum salmon are the most abundant species present, and that the length frequency distributions of resident and migratory species are almost mutually exclusive.

Key Words: chinook salmon, chum salmon, split beam, fisheries hydroacoustic, Yukon River

INTRODUCTION

The Yukon River flows 3,700 km (2,300 mi) from its headwaters in British Columbia to Norton Sound on the Bering Sea Coast of Alaska, and drains an area of approximately 330,000 square miles. Chinook salmon (*Oncorhynchus tshawytscha*) and chum salmon (*O. keta*) travel through various fisheries as they migrate up the Yukon River toward their spawning grounds, some of which are in Canada. Alaskan fisheries are managed by the Alaska Department of Fish and Game (ADF&G) while Canadian fisheries are managed by the Canada Department of Fisheries (CDFO). Fisheries managers in Alaska and Canada have long been interested in the number of salmon that cross the border, and research activities to evaluate border passage have been based on relative fishwheel capture rates, tag/recovery data, and aerial surveys of spawning streams. However, because of the variability inherent to these assessment techniques, the U.S./Canada Joint Technical Committee (JTC) has identified the need for more accurate, timely data on the number of salmon passing the U.S./Canada border.

In response to the need for more accurate abundance estimates, the JTC appointed a Sonar Planning Subcommittee to develop a plan for investigating the feasibility of using sonar to estimate the number of Yukon River salmon entering Canada. The Subcommittee was comprised of representatives from ADF&G, U.S. Fish and Wildlife Service (USFWS) and CDFO. In 1991, Subcommittee members agreed to a four year project plan and USFWS staff attended a formal week-long hydroacoustic workshop. Split-beam hydroacoustic equipment was purchased, potential sonar sites were surveyed, and the land status of the potential sites was determined.

This report summarizes the results achieved during the 1992 field season. The second year field season goals specified in the Yukon River Border Sonar Project Operational Plan are:

1) Procure all additional support equipment necessary to successfully conduct the project.
2) Construct one main project camp facility and two sonar data acquisition tents.
3) Verify that the sonar system is capable of detecting a target of known acoustic size in the Yukon River at the selected sites.
4) Optimize sonar beam pattern geometry to the river cross-section at the exact transducer locations.
5) Develop *in situ* split-beam sonar calibration procedures.
6) Determine the feasibility of drift gillnetting in the Yukon River near the sonar site.
7) Identify fish species present in the study area during the periods of operations.
8) Acquire acoustic and gillnet data to describe the spatial distribution of fish present the periods of sonar operations.
9) Acquire acoustic and gillnet data for developing procedures to estimate the acoustic size of fish present in the study area.

METHODS

Site Description

The Yukon River at the U.S./Canada border is characterized by a single channel with islands and stable banks (Figure 1). The site, 2 km downstream from Eagle, Alaska at river km 1,952 (river mi 1,213) was chosen because of the single, narrow channel, proximity to the border at river km 1,970 (river mi 1,224), and nearly linear bottom slope outward from both banks (Figure 2). Several transects were conducted in the immediate vicinity of the sonar site using a Lowrance model X-15[1] portable depth sounder to identify the most suitable location to deploy the sonar equipment. The river at the sonar site varies from 275 m to 305 m in width and from 10 m to 15 m in depth depending on the time of year and precipitation. The left bank bottom begins at the base of a cliff and slopes steeply to the thalweg at about 90 m. The right bank is sandy and more gradually sloped.

Camp Construction

Beginning on 5 July, the field camp was constructed on a level area approximately 50 m from the left bank and 0.5 km downriver from lower Eagle Bluff. Camp facilities included one Weatherport tent each for cooking, storage, and sleeping, and one additional wall tent for sleeping. In addition, two Weatherport tents were built on each bank directly across the river from each other approximately 300 m upstream from the camp site to house the sonar equipment. Equipment on each bank was powered with 110 VAC supplied by one Honda model EM-3500 gasoline generator positioned about 50 m behind each sonar tent. An office and a warehouse were maintained in Eagle to facilitate communication, data processing and food storage.

Sonar Data Acquisition

Split-beam sonar equipment deployed on both banks consisted of an HTI model 240 Digital Echo Sounder (DES) to send and receive electronic signals, an HTI model 340 Digital Echo Processor (DEP) with an internal HTI model 404 Chart Recorder Interface (CRI) connected to a Panasonic model KXP-1624 dot-matrix printer, and a Nicolet model 310 digital storage oscilloscope (DSO) with on-board tandem 3.5-in floppy drives. Digitized raw echoes were periodically recorded on a Panasonic model SV-3700 digital audio tape (DAT) recorder. International Transducer Corporation (ITC) elliptical split-beam transducers with nominal beam dimensions of 2.5°x10°, 4°x10°, and 6°x10° were used to transmit and receive sound pulses. Transducers were mounted on aluminum tripods placed 2 m to 7 m offshore, and remotely-aimed with a Remote Ocean Systems (ROS) model PT-25 dual-axis pan and tilt rotator and ROS model PTC-1 pan and tilt control unit with real-time angular position feedback accurate to 0.3°.

---

[1]Use of a company's name does not constitute product endorsement by ADF&G.

Sound pulses were generated by the transceiver at a frequency of 200 kHz. Pulse widths of 0.4 ms, 0.6 ms, and 0.8 ms were used to acquire data at various times. We used different pulse widths on each bank to prevent crosstalk between sounders. Pulse repetition frequencies varied between 5 and 10 Hz. Effective listening ranges varied from 10 m to 90 m on the left bank, and from 55 m to 82 m on the right bank. Returning echoes, filtered for correct frequency (within plus or minus 2.5 kHz), half-amplitude pulse width, threshold voltage, and range were routed through the CRI in the DEP to the printer. Chart recording thresholds were adjusted as conditions and aim warranted.

The DES and DEP were user-configured in software. The DES was configured for transmit power, pulse duration, trigger source, data routing, frequency bandwidth, receiver gain, pulse repetition frequency (PRF), calibration pulse spacing, time-varied gain (TVG) spreading loss factor and effective range, attenuation coefficient, receiver channel selection criteria, and internal/external calibration operation. The DEP allowed user-controlled filtering of returning echoes for pulse width, start and end processing range, range-dependent minimum voltage thresholds, maximum allowable angle off-axis in the horizontal and vertical planes, and maximum combined angle off-axis in dB. Tracking parameters which were user-configured in the DEP included the minimum number of pings required to constitute a fish, the maximum consecutive number of pings allowed to drop out within a single tracked fish, the maximum allowable change in range (expressed in m/s), and the maximum and minimum allowable tracked fish velocities (m/s). Echogram (chart recording) parameters, also user-controlled in DEP software, consisted of start and end processing ranges, a single minimum voltage threshold, paper speed (echoes/line), and echogram resolution (in terms of 9 vs 24-pin printer type).

Information from all processed signals were automatically written to three separate ASCII files at specified time intervals; a file with a *.raw* extension comprised of information from all echoes which met filtering criteria, a file with an *.ech* extension containing information from each echo aggregated into groups likely to have come from a single tracked fish, and a file with an *.fsh* extension containing one line of summary information from each tracked fish. File nomenclature was controlled in proprietary software, and consisted of the bank (R or L), Julian date, and hour and minute that the file was opened. For example, R2600815 would be the name of a file from the right bank opened on Julian date 260 (16 September 1992) for a sampling interval that began at 0815 hours).

Whenever possible, the sonar equipment on each bank ran continuously 24 h per day, seven days per week except for half-hour periods around 0900 hours and 2100 hours. During those times, the generator was refueled and maintained. The equipment was monitored opportunistically from 0800 hours through 2200 hours daily, and it typically operated unmonitored during the remainder of the day.

In Situ Calibration

A variety of spherical standard targets of known acoustic size were ensonified at many positions in the beam early in the period of data collection to verify the system's ability to detect the targets and estimate their target strength.

Targets which were heavier than water were suspended a known distance beneath the water surface on a strand of monofilament line. The buoyant target was anchored by a similar strand of monofilament line. The targets we suspended in the beam were: 1) a 38.1 mm stainless steel sphere; 2) a 24.5 mm electrical grade copper sphere; 3) a ping pong ball; and 4) a 90 mm lead sphere (10 lb downrigger fishing weight). We measured the echo voltage of each target as close to the maximum response axis (MRA) as possible. We determined exact target position in the beam by measuring phase in the up-down and right-left axes on a DSO, and aligning the paired phase angles along both axes. Using calibration data in the signal processing software, the DEP calculated target strength estimates in real time. Finally, we compared our measured target strength values to theoretical values which we calculated following Urick (1983) as:

$$TS = 10 \log\left(\frac{\sigma}{4 \cdot \Pi}\right) \tag{1}$$

where: TS = target strength in dB

σ = backscattering cross-section in m^2

Sonar Beam Pattern Geometry

We calculated maximum potential beam dimensions based on river bottom profiles from depth soundings at the site. The greatest possible beam dimension in the vertical plane was calculated as:

$$\theta = 2 \cdot \arctan\left(\frac{d}{2r}\right) \tag{2}$$

where: θ = angular beamwidth

d = depth

r = range

We chose elliptical beam transducers whose narrow axis most completely filled the water column on each bank from the suite of transducers manufactured for this project. The transducers were positioned in the river perpendicular to the current with the wide axes of the beams oriented as close to a horizontal position as possible to increase the number of echoes recorded for each tracked fish.

Spatial Distribution

Since each echo fixed the target's three-axis position in the beam, we were able to describe the spatial distribution of all fish which passed within the ensonified range on each bank. Direction of travel in terms of net upstream or downstream movement was calculated in software as the difference between the initial and final x-axis position for each tracked fish.

Training

A one-day formal training session was conducted by HTI in Eagle on 17 July to familiarize project personnel with the operating characteristics of the sonar equipment. Training included a review of the system components and field assembly. It also included an explanation of the acquisition and signal processing control software. A second training session was presented on 8 September detailing modifications to the control software.

Test Fishing

Test fishing activities began after the sonar equipment was operational, and continued as time allowed during the remainder of July and September. Drift and set gillnets were used to catch fish in the immediate vicinity of the sonar site in 1992. Five nets with the following dimensions were used in the course of test fishing:

1) 45.7 m long, 7.6 m deep, 64 mm (2.5 in) mesh multifilament
2) 45.7 m long, 7.6 m deep, 89 mm (3.5 in) mesh multifilament
3) 45.7 m long, 3.6 m deep, 127 mm (5.0 in) mesh multifilament
4) 45.7 m long, 7.6 m deep, 140 mm (5.5 in) mesh multifilament
5) 45.7 m long, 7.6 m deep, 190 mm (7.5 in) mesh multifilament

Drifts were conducted with one end of the net as close to shore as possible and the offshore end held in position with a boat. Typical drifts of about five minutes in duration were limited by the ability to keep the nets oriented perpendicular to shore. Sets were made less than 200 m downstream of the transducers on each bank with one end of the net onshore. All gillnets were fished as perpendicular to the current as possible.

Test fishing times (FT) were calculated as:

$$FT = (FI-FO) + \frac{(FO-SO)+(FI-SI)}{2} \tag{3}$$

where: SO = time at beginning of net deployment
FO = time when the net is fully deployed
SI = time at beginning of net retrieval
FI = time when the net is fully retrieved

Captured fish were tallied by species. Salmon were sampled for mid-eye to fork of tail length and sex. Resident species were measured for tip of snout to tail fork length. All sampling mortalities were given to local residents.

Data Processing

Since this was the first application of a new technology to sample free swimming fish in a river, it was necessary to verify the system's ability to detect and track fish. In order to optimize our limited data processing resources, analysis was limited to times of peak abundance which we determined by visually scanning the echograms.

Initial data processing involved reducing the electronic data to include only echoes certain to have come from fish. This was accomplished by locating tracked fish from electronic (*.ech*) data files on simultaneously collected echograms using information such as time, range, residence time in the beam, change in range, and proximity to nearby targets. All assemblages of valid echoes not likely to have originated from fish (bottom traces, for example) were deleted from the data files. In addition, echoes from a single fish which was electronically tracked as two or more fish, were manually combined in the data files.

Echograms were reviewed to identify targets not tracked in software which appeared to be fish. Echoes from these targets were located in the corresponding *.raw* files to determine the reasons that the software failed to classify the assemblages of echoes as fish. Where appropriate, the tracking parameters were adjusted, and the *.raw* files were re-run using the updated criteria.

After the data were reduced to include only valid echoes from tracked fish, we calculated within and between-fish target strength means and variances. We also summarized spatial distribution, and direction of travel. Similarly, standard target data were analyzed to estimate the target strength mean and standard deviation for each type of standard target we ensonified.

RESULTS

Sonar Site Location

The transducer placement adequately satisfied first year objectives; the bottom slopes on both banks were essentially linear and stable (Figure 2). The left bank slope was steep and rocky while the right bank slope was more gradual and sandy. River velocity was 1.5 m/s, and we didn't encounter any unusual problems deploying the transducers. After aiming, we were able to detect bottom and fish echoes at ranges of 90 m from the right bank and 82 m from the right bank.

The river level at the sonar site dropped continually from the first day of operation, subsiding a total 3.7 m (12 ft) during the course of the project (Table 1). The receding water level forced us to move the transducers further offshore several times during the course of data collection.

Beam Fitting

At the onset of the project, the river was 305 m wide where the transducers were located, and the thalweg was 13 m deep at 90 m from the left bank (Figure 2) resulting in calculated bottom slopes of 8.2° and 3.5° on the left and right banks. To optimize river coverage at these bottom slopes, we deployed nominal 6°x10° (7.3°x11.3° effective) beam width and 2.5°x10° (2.7°x9.5° effective) beam width elliptical transducers on the left and right banks, and were able to detect fish targets at resulting noise levels.

Sonar Data Acquisition

In all, 705 h of simultaneous echogram and electronic split-beam acoustic data were collected during sonar operations in 1992 (Table 2). Of that, 372 h were collected on the left bank and 333 h were collected on the right bank. The field season was separated into two operational periods based on existing DFO fishwheel information which indicated that the chinook salmon migration predominantly occurs in July while chum salmon migrate past the border mainly in September (Milligan et al. 1985, 1986). We were able to collect 112.5 h of left bank data and 84.1 h of right bank data from 20 July through 2 August. An additional 259.5 h and 248.9 h of acoustic data were collected from 6 through 22 September on the left and right banks. The maximum effective listening ranges we achieved were 90 m on the left bank and 82 m on the right bank.

Data Reduction and Processing

We limited data reduction and analysis to only those data which we felt were of the best quality based on largest signal-to-noise ratio (SNR) and abundance of detected fish. To date, we have reduced and analyzed 39.4 h of left bank and 58.9 h of right bank acoustic data acquired in September (Table 3). During those sampling intervals, we tracked 294 individual fish on the left bank and 1,904 fish on the right bank. Of those, 261 fish (89 %) and 1,603 fish (84 %) were tracked as upstream migrants on the left and right banks. None of the data acquired prior to the September sampling period were reduced or analyzed by the time this report was written.

In the data we analyzed, the estimated mean target strength of all tracked targets was -36.98 dB (SD = 2.21) and -34.05 db (SD = 3.54) on the left and right banks (Table 3). Mean daily target strength estimates varied from -36.89 dB to -37.53 dB on the left bank and from -33.45 dB to -34.34 dB on the right bank. Appendix A.1 shows the target strength distribution on 16 September 1992. Standard deviations varied from 1.60 to 2.26 on the left bank and from 3.22 to 3.74 on the right bank. The larger target strengths and increased variability observed on the right bank likely resulted to an unknown degree from a higher threshold setting required on that bank due to higher inherent noise levels. The distribution of target strength estimates depicted in Figure 3 resembles the length distributions from the Yukon River District 5 and District 6 commercial catch samples (Figure 4) as well as the second mode of the gillnet samples from the sonar test fishery (Figure 5). In addition, the body length distribution of fish caught in the test fishery was distinctly bimodal with the larger (chum salmon) mode completely separated from the smaller (resident species) mode.

In order to be classified as a fish, we specified that each tracked target must be comprised of no less than five valid echoes. Standard deviations of within fish target strength estimates on the peak day of detected passage (16 September) were normally distributed with a mean of 3.8 dB and standard deviation of 1.53 dB (Figure 6).

Spatial Distribution

The daily spatial distribution of fish passing through the right bank sonar beam at range and depth is shown in Appendix A.2. This graph clearly shows the 'hard edge' effect of split-beam data in which effective beamwidth is not influenced by target size (for targets larger than the minimum detection threshold at the -6 dBv beam edge). Preliminary results indicate that the fish we tracked were located throughout the ensonified water column and across the entire listening range, with a slight tendency toward bottom orientation.

In Situ Calibrations

A total of 3 h of *in situ* calibration data was collected in July using targets of known acoustic size suspended in the beam. Measured on-axis target strengths of -43.93 dB for a ping pong ball, -42.97 dB for a 25.4 mm diameter copper sphere, -42.24 dB for a 38.1 mm diameter stainless steel sphere, and -34.95 dB for an 89.0 mm diameter lead sphere (10 lb downrigger weight) were close to theoretical values, and standard deviations about the estimates were small (Table 4). In addition to target strength distributions (Appendices B.1-B.4), the histogram displayed in Figure 7 shows that the distribution of *in situ* beam pattern factors (BPF) of an on-axis 38.1 mm stainless steel sphere was unimodal with the mode at the maximum response axis (MRA). The mean BPF was -1.01 dB, and the standard deviation was 1.1 dB.

Test Fishing

Gillnet test fishing began on 27 July and terminated on 21 September (Table 5). Both set and drift gillnets were used to catch fish during July. However, only set gillnets were deployed after 1 August. A total 871 fish were caught during 276.8 h of sonar-related test fishing activities. In addition to two species of salmon, ten species of resident fish were caught (Table 6). Catches included 31 chinook salmon, 708 chum salmon, 55 whitefish (Corregonus spp), and 77 other resident fish. These catches may not reflect precise relative or temporal abundance between or within species since they were not adjusted for net selectivity or effort. However, only one whitefish and few other resident species were caught prior to September, and the total number of resident fish caught during September represented a small fraction (13 %) of the number of chum salmon caught during that time. Additionally, the mean lengths of six of the ten resident species were more than two standard deviations smaller than the mean length of chum salmon captured.

DISCUSSION

While split-beam technology is not new (Carlson and Jackson 1980), as far as we know, this was the first attempt to use split-beam hydroacoustic equipment to assess fish abundance in a river. In addition, this was the first field deployment of this prototype model sonar system. Split-beam was identified as the technology of choice primarily because of its: 1) theoretical advantage over dual-beam to precisely measure *in situ* target strength (Ehrenberg, 1983); 2) demonstrated ability (in marine applications) to precisely fix the target's three-axis position in the beam; and 3) ability to complete these tasks in real time. Fixing three-axis target position, for the first time, allows us to precisely describe fish distribution within the ensonified water column. It also allows us to unambiguously determine each tracked target's direction of travel in real time. Past uncertainties associated with direction of travel questions at other single and dual-beam riverine sonar programs have at times eroded confidence in abundance estimates generated by those projects.

As technologically advanced as the split beam sonar equipment was, we encountered a number of unanticipated difficulties which inhibited our abilities to fully achieve all second year project objectives. This was the first field season of a feasibility project, designed to evaluate whether or not it is possible to assess the number of chinook and chum salmon migrating past the border into Canada. The sonar equipment arrived on site from the manufacturer just at the onset of the chinook salmon migration. The loss of installation contingency time meant that a large portion of the chinook salmon migration was inadequately sampled while typical first season installation technicalities were resolved, and while agency staff became facile with hardware operation.

Further delays in systematic data acquisition were encountered in July as hardware and software deficiencies were discovered. Data acquisition gradually ceased as each DES eventually erased its time-varied gain (TVG) erasable, programmable, read-only memory (EPROM), which corrects echo voltage for spreading loss. This problem was corrected by the manufacturer during the August quiescent period. In addition to the hardware problem, electronic file management software malfunctioned periodically and unexpectedly throughout the period of data collection. This software was designed to automatically open and close data files based on user-specified time intervals. Typically, active data files were to be closed and new data files opened at the start of each hour. The malfunction allowed files to be opened and closed at irregularly-timed intervals resulting in data files of variable length. Some of the largest files contained more than 25 mbytes of data, making data reduction and secure storage on floppy disks difficult. In extreme cases during periods of unmonitored operation, continuously open files filled the data buffers in the DEP and data acquisition ceased. Data reduction and analysis difficulties due to variable file duration were compounded by additional software deficiencies including an inability to annotate chart recordings at regular time and range intervals since the first step in data reduction involves manually verifying automatically tracked fish on chart recordings, and fish are located on echograms by range and time.

In addition to programming bugs, our ability to conduct inseason and post-season data analysis was severely inhibited by elements of the software package which were not completed until March 1993. The most important of these programs was one which allowed us to reprocess raw data files using amended tracking parameter values. As an alternative, limited DAT data were available for analysis. However, it was our understanding that all of the hardware required to replay those data were being modified by the manufacturer after the field season and were not available.

A final impediment to successful data acquisition and analysis on this project during its initial field season was caused by a system design characteristic which enhanced the probability of erroneous system operation. The DES and DEP were both user controlled in software. However, each was independently controlled by a separate set of manually-entered control parameter values. Because many tracking and filtering decisions are based in part on DES acquisition settings, any discrepancy between manually entered DES and DEP settings resulted in erroneously acquired data. This problem was exacerbated by the absence of any mechanism allowing interrogation of the DES settings once they had been entered, and further by the lack of a mechanism to record the sounder settings used to acquire data. In order for the gear to be fully field deployable, a software or hardware modification must be developed to allow user access to DES settings while the system is active. An additional design improvement which would greatly enhance the system's utility would be to have the DEP interrogate the DES for all settings required as input to tracking software, and to automatically write all processing and filtering parameter values to the open data file at each change of acquisition or tracking parameter values.

In spite of these correctable shortcomings, once the system was functioning it was clearly capable of acquiring target strength and three-axis position data from fixed standard targets and free-swimming fish in real time. Target strength estimates of standard targets were very close to theoretical values, and target strength estimates of free-swimming fish were reasonable based on salmon body length:target strength relationships we developed using dual-beam sonar on the Kenai River (unpublished data), and on published body length:target strength relationships established for other species (Foote et al 1986; Love 1977).

Two very real advantages of using measured phase angle data to determine target position in the beam are that: 1) all signal processing occurs in real time (in contrast to dual beam target strength estimates which are generated during post-acquisition data processing); and 2) little uncertainty exists about the target's position in the beam. Real time target strength estimation allows rapid evaluation of system settings and fish size. This ability shortens reaction time and facilitates collection of ancillary, often non-acoustic data to verify acoustic results which is especially important during the developmental phase of a field project. In contrast to the concept of differential echo amplitude measurement employed by dual beam sonar systems, absolute knowledge of target position based on paired phase-angle measurements creates a uniform effective beamwidth for all extra-threshold targets (at 3 dB off of the MRA), giving the beam a 'hard edge'. This allows calculation of swimming speed and reduces detection and tracking bias caused by larger fish generating more echoes than smaller fish. In addition, calculated beam pattern factors we achieved from a standard target fixed on the MRA peaked at and were nearly all less than zero (the largest theoretically possible value). In contrast, we have found that beam pattern factors greater than zero may be expected in at least 10 percent of the echoes acquired with a well tuned dual beam sonar system (unpublished data).

One of the uncertainties remaining after analysis of the 1992 acoustic data involves noise levels we observed *in situ*. Although we were not able to clearly establish the proportionate contributions of environmental and machine noise, it is clear that environmental factors on both banks resulted in relatively high background noise levels. The right bank bottom slope was shallow which increased surface reverberation from the surface of the river. The left bank, while steeply sloped, had a rocky bottom populated with large boulders which readily reflect transmitted sound, another form of surface reverberation. Because we understood that the entire sonar system was in modification by the manufacturer since the end of the field season, we were not able to replay taped data to describe river noise amplitude and variability.

In addition to environmental noise, the system was characterized by high noise levels, even when not aimed near the surface or bottom of the river, and with the transmit power and receive sensitivity set at the lowest levels possible. We are anticipating that post-season modifications to enable reduced transmit power and receiver gain settings in the units used during the 1992 field season will significantly reduce noise levels below those observed inseason.

Regarding non-acoustic sampling, most of the test fishing was conducted with set gillnets due to swift river current at the site. This made effort documentation difficult since set gillnets often flag in current and become entangled in debris. In addition, fishing with set gillnets limited sampling to nearshore areas. Therefore it was not meaningful to calculate relative gillnet efficiency and hence not possible to correct for mesh-specific catchability. It was also impossible to document the spatial distribution of migrating fish, since the mid-section of the river was not sampled. However, it is worthwhile to note that during the time whitefish were present, catches of chum salmon were larger than catches of whitefish in all mesh sizes used. We used gillnets mainly to document the presence or absence of species through time, to collect samples for fish size information, and to monitor temporal changes in abundance within species. Based on upriver fishwheel data, we were initially under the impression that very few salmon migrated past the sonar site during the month of August. However, 24 fish, including 5 chinook salmon and 11 chum salmon were caught in a 127 mm mesh set gillnet deployed for 69.5 h from 18-21 August. Therefore, it will be necessary to acoustically sample the migration continuously from early July through September in the coming field season.

LITERATURE CITED

Carlson, T.J., and D.R. Jackson. 1980. Empirical evaluation of the feasibility of split beam methods for direct *in situ* target strength measurement of single fish. University of Washington Applied Physics Laboratory (APL-UW 8006). Seattle.

Ehrenberg, J.E. 1983. A review of *in situ* target strength estimation techniques. FAO Fisheries Report. 300:85-90. Rome.

Foote, K.G., A. Aglen, and O. Nakken. 1986. Measurement of fish target strength with a split-beam echo sounder. Journal of the Acoustical Society of America. 80(2):612-621.

Love, R.H. 1971. Maximum side-aspect target strength of an individual fish. Journal of the Acoustic Society of America. 46(2):746-752.

Milligan, P.A., W.O. Rublee, and R.A.C. Johnson. 1985. The distribution and abundance of chinook salmon (*Oncorhynchus tshawytscha*) in the upper Yukon River basin as determined by a radio-tagging and spaghetti tagging program: 1982-1983. Canada Department of Fisheries and Oceans, Field Services Branch, Can. Tech. Rep. of Fish. and Aquatic Sci. 1350. New Westminster.

Milligan, P.A., W.O. Rublee, and R.A.C. Johnson. 1986. The distribution and abundance of chum salmon (*Oncorhynchus keta*) in the upper Yukon River basin as determined by a radio-tagging and spaghetti tagging program: 1982-1983. Canada Department of Fisheries and Oceans, Field Services Branch, Can. Tech. Rep. of Fish. and Aquatic Sci. 1351. New Westminster.

Urick, R.J. 1983. Principles of underwater sound. 3rd edition. McGraw-Hill, New York.

Table 1. Daily mean water level measured at Eagle, Alaska from July through September, 1992.[1]

Date	Gauge Ht. (m)	Date	Gauge Ht. (m)	Date	Gauge Ht. (m)
7/01/92	7.56	8/01/92	5.79	9/01/92	4.35
7/02/92	7.33	8/02/92	5.68	9/02/92	4.31
7/03/92	7.25	8/03/92	5.60	9/03/92	4.29
7/04/92	7.25	8/04/92	5.56	9/04/92	4.34
7/05/92	7.28	8/05/92	5.50	9/05/92	4.42
7/06/92	7.34	8/06/92	5.38	9/06/92	4.46
7/07/92	7.34	8/07/92	5.28	9/07/92	4.47
7/08/92	7.36	8/08/92	5.25	9/08/92	4.45
7/09/92	7.33	8/09/92	5.21	9/09/92	4.40
7/10/92	7.30	8/10/92	5.12	9/10/92	4.37
7/11/92	7.16	8/11/92	5.12	9/11/92	4.33
7/12/92	7.03	8/12/92	5.18	9/12/92	4.26
7/13/92	6.90	8/13/92	5.17	9/13/92	4.18
7/14/92	6.90	8/14/92	5.17	9/14/92	4.13
7/15/92	7.10	8/15/92	5.10	9/15/92	4.08
7/16/92	7.26	8/16/92	5.08	9/16/92	4.03
7/17/92	7.32	8/17/92	4.98	9/17/92	3.97
7/18/92	7.50	8/18/92	4.87	9/18/92	3.89
7/19/92	7.55	8/19/92	4.90	9/19/92	3.84
7/20/92	7.40	8/20/92	4.84	9/20/92	3.77
7/21/92	7.46	8/21/92	4.72	9/21/92	3.71
7/22/92	7.58	8/22/92	4.64	9/22/92	3.65
7/23/92	7.51	8/23/92	4.64	9/23/92	3.60
7/24/92	7.21	8/24/92	4.62	9/24/92	3.54
7/25/92	6.86	8/25/92	4.60	9/25/92	3.47
7/26/92	6.56	8/26/92	4.58	9/26/92	3.40
7/27/92	6.34	8/27/92	4.58	9/27/92	3.40
7/28/92	6.28	8/28/92	4.58	9/28/92	3.30
7/29/92	6.20	8/29/92	4.53	9/29/92	3.27
7/30/92	6.07	8/30/92	4.46	9/30/92	3.24
7/31/92	5.93	8/31/92	4.40		

1. Data from U.S. Department of Interior, Geological Survey, Alaska District.

Table 2. Summary of split beam sonar data collected at Eagle, Alaska from 20 July through 22 September 1992 by date and bank.

Date	Left Bank Time (h)	Left Bank Range (m)	Right Bank Time (h)	Right Bank Range (m)	Total Hours
07/20	2.8				2.8
07/21	3.8				3.8
07/22	6.3	10			6.3
07/23	1.8	30			1.8
07/24	0.3	20			0.3
07/25	12.5	20			12.5
07/26	0.6	20			0.6
07/27	1.2	60	4.9		6.1
07/28	19.0	90	4.8	64	23.8
07/29	14.0	90	11.2	55	25.2
07/30	19.5	90	15.7	55	35.2
07/31	10.9	74	21.3	82	32.2
08/01	19.8	74	20.5	82	40.3
08/02			5.7	82	5.7
Subtotal	112.5		84.1		196.6
09/06	9.5				9.5
09/07	18.6		5.0		23.6
09/08	20.5		20.8	75	41.3
09/09	18.7	70	18.5	75	37.2
09/10	16.5	58			16.5
09/11	14.7	58	19.4		34.1
09/12	14.7	58	23.0		37.7
09/13	10.0	69	17.8		27.8
09/14	12.8	69	6.3		19.1
09/15	12.6	69	7.6	50	20.2
09/16	19.1	69	22.9	50	42.0
09/17	18.0	69	18.9	50	36.9
09/18	7.7	69	9.5	50	17.2
09/19	19.1	69	22.0	50	41.1
09/20	22.7	69	23.2	50	45.9
09/21	20.8	69	23.4	50	44.2
09/22	3.5	69	10.6	50	14.1
Subtotal	259.5		248.9		508.4
Total	372.0		333.0		705.0

Table 3. Summary of processed split beam acoustic data from the Yukon Border sonar project in 1992.

Date	Time (hrs)	Bank	Number Upstream	Number Downstream	Total Tracked Fish	Mean Target Strength (dB)	Standard Deviation
09/11	14.7	Left	20	12	32	- 37.53	1.60
09/12	14.7	Left	107	12	119	- 36.93	2.14
09/13	10.0	Left	134	9	143	- 36.89	2.26
Subtotal	39.4		261	33	294	- 36.98	2.21
09/15	7.6	Right	391	49	440	- 33.75	3.59
09/16	22.9	Right	1,044	170	1,213	- 34.27	3.47
09/17	18.9	Right	15	5	20	- 34.34	3.22
09/18	9.5	Right	153	77	230	- 33.45	3.74
Subtotal	58.9		1,603	301	1,904	- 34.05	3.54
Total	98.3		1,864	334	2,198	- 34.44	3.54

Table 4. Summary of *in situ* target strength estimates from four types of standard targets measured with split-beam hydroacoustic equipment in the Yukon River at Eagle, Alaska in 1992.

Target	Minutes Ensonified	No. of Echoes	Mean TS (dB)	Sample SD	Theoretical TS (dB)
Ping pong[1]	6	841	-43.93	1.46	-41.50
Copper[2]	21	220	-42.97	1.20	-43.94
Stainless[3]	62	2429	-42.24	1.88	-40.42
Lead[4]	95	2018	-34.95	4.06	-32.96
Total	184				

[1] Standard 36.5 mm ping pong ball.
[2] Electrical grade copper sphere, 25.4 mm in diameter.
[3] Stainless steel sphere, 38.1 mm in diameter.
[4] Lead sphere, 89.0 mm in diameter.

Table 5. Fish caught in sonar-related test fishing activities at Eagle, Alaska in 1992 by species and gear type.

Date	Gear Type	Time (hrs)	Mesh (cm)	Chinook Salmon	Chum Salmon	White-fish [1]	Other fish [2]	Total
07/27	Drift	0.2	19.0 [3]	4	0	0	0	4
07/29	Set	6.2	12.7 [3]	6	0	0	0	6
07/29	Drift	0.5	8.9 [3]	1	0	0	0	1
07/29	Drift	0.4	14.0 [3]	2	0	0	0	2
07/29	Drift	0.5	19.0 [3]	3	0	0	0	3
07/30	Set	7.0	12.7 [4]	3	0	0	0	3
07/30	Drift	0.4	14.0 [3]	3	0	0	0	3
07/30	Drift	0.2	19.0 [3]	2	0	0	0	2
07/31	Drift	0.1	19.0 [3]	1	0	0	0	1
07/31	Set	1.8	19.0 [3]	1	0	0	0	1
08/01	Set	11.4	6.4 [3]	0	0	0	3	3
08/18	Set	9.0	12.7 [4]	1	0	0	0	1
08/19	Set	24.0	12.7 [4]	2	2	0	2	6
08/20	Set	24.0	12.7 [4]	2	5	0	3	10
08/21	Set	12.5	12.7 [4]	0	4	1	2	7
09/06	Drift	0.7	14.0 [3]	0	1	0	0	1
09/06	Drift	0.5	8.9 [3]	0	0	1	0	1
09/07	Set	7.1	8.9 [3]	0	8	8	10	26
09/07	Set	6.8	14.0 [3]	0	12	0	0	12
09/08	Set	7.1	14.0 [3]	0	38	1	0	39
09/08	Set	7.0	8.9 [3]	0	11	5	5	21
09/09	Set	7.5	8.9 [3]	0	17	5	6	28
09/09	Set	7.4	14.0 [3]	0	37	1	2	40
09/10	Set	6.8	14.0 [3]	0	54	0	0	54
09/10	Set	7.0	8.9 [3]	0	15	9	4	28
09/11	Set	4.4	14.0 [3]	0	22	0	1	23
09/11	Set	4.4	8.9 [3]	0	6	3	3	12
09/12	Set	3.2	14.0 [3]	0	19	0	0	19
09/12	Set	3.3	8.9 [3]	0	8	5	4	17
09/13	Set	5.6	8.9 [3]	0	18	5	7	30
09/13	Set	5.7	14.0 [3]	0	41	0	0	41
09/15	Set	7.5	6.4 [3]	0	20	1	3	24
09/15	Set	7.4	14.0 [3]	0	35	1	0	36
09/16	Set	7.2	14.0 [3]	0	42	0	0	42
09/16	Set	7.1	8.9 [3]	0	20	3	3	26
09/17	Set	7.7	14.0 [3]	0	42	0	0	42
09/17	Set	8.0	8.9 [3]	0	16	1	3	20
09/18	Set	6.8	8.9 [3]	0	19	0	3	22
09/18	Set	6.7	14.0 [3]	0	71	0	0	71
09/19	Set	6.6	14.0 [3]	0	29	0	0	29
09/19	Set	6.8	8.9 [3]	0	18	3	6	27
09/20	Set	4.3	8.9 [3]	0	6	1	3	10
09/20	Set	4.4	14.0 [3]	0	28	0	0	28
09/21	Set	6.7	14.0 [3]	0	31	0	0	31
09/21	Set	6.9	8.9 [3]	0	13	1	4	18
Total		276.8		31	708	55	77	871

[1] Includes least cisco, Bering cisco, broad whitefish, and humpback whitefish.

[2] Includes burbot, longnose sucker, northern pike, sheefish, and arctic grayling.

[3] Net measurements are 45.7 m long and 8.3 m deep.

[4] Net measurements are 45.7 m long and 3.6 m deep.

Table 6. Mean length and standard deviation of fish caught in sonar-related gill net test fishing activities at Eagle, Alaska in 1992 by species.[1]

	Sample Size	Mean Length (mm)	Sample S.D.
Chinook salmon	31	713.58	173.25
Chum salmon	708	608.51	39.23
Longnose sucker	26	386.26	36.08
Burbot	1	650.00	
Sheefish	27	504.93	130.57
Northern Pike	5	628.00	85.12
Bering cisco	25	383.48	18.05
Round whitefish	1	405.00	
Broad whitefish	3	500.00	72.11
Humpback whitefish	17	395.94	56.70
Arctic grayling	18	353.39	36.06
Least Cisco	9	341.83	21.20
Total	871		

[1] Catches combined for all mesh sizes used.

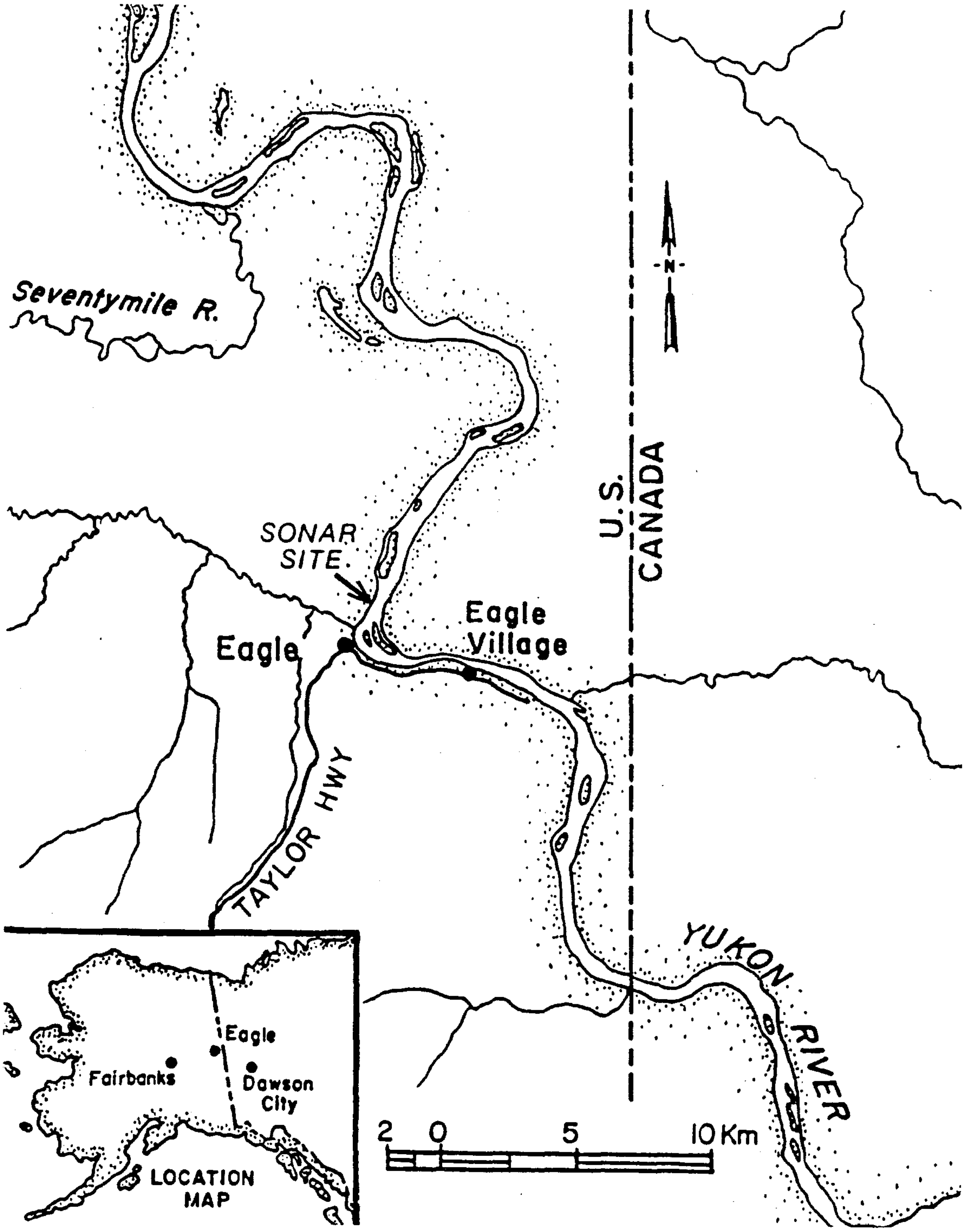


Figure 1. Map of the Yukon River near the U.S.-Canada border showing the location of the 1992 sonar site and Eagle, Alaska.

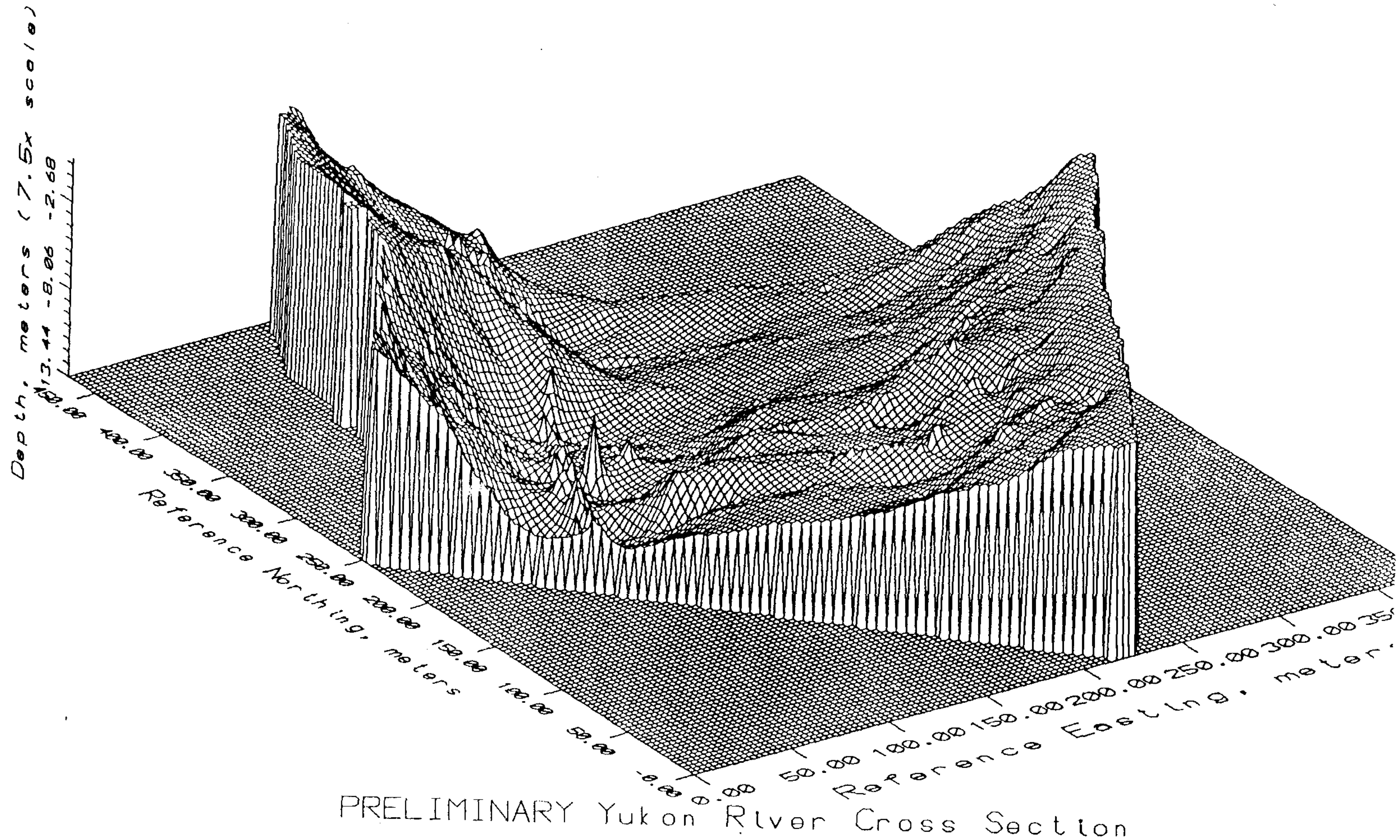


Figure 2. Yukon River bottom map on 27 July 1992 at the sonar site. (Data courtesy of Chad P. Gubala)

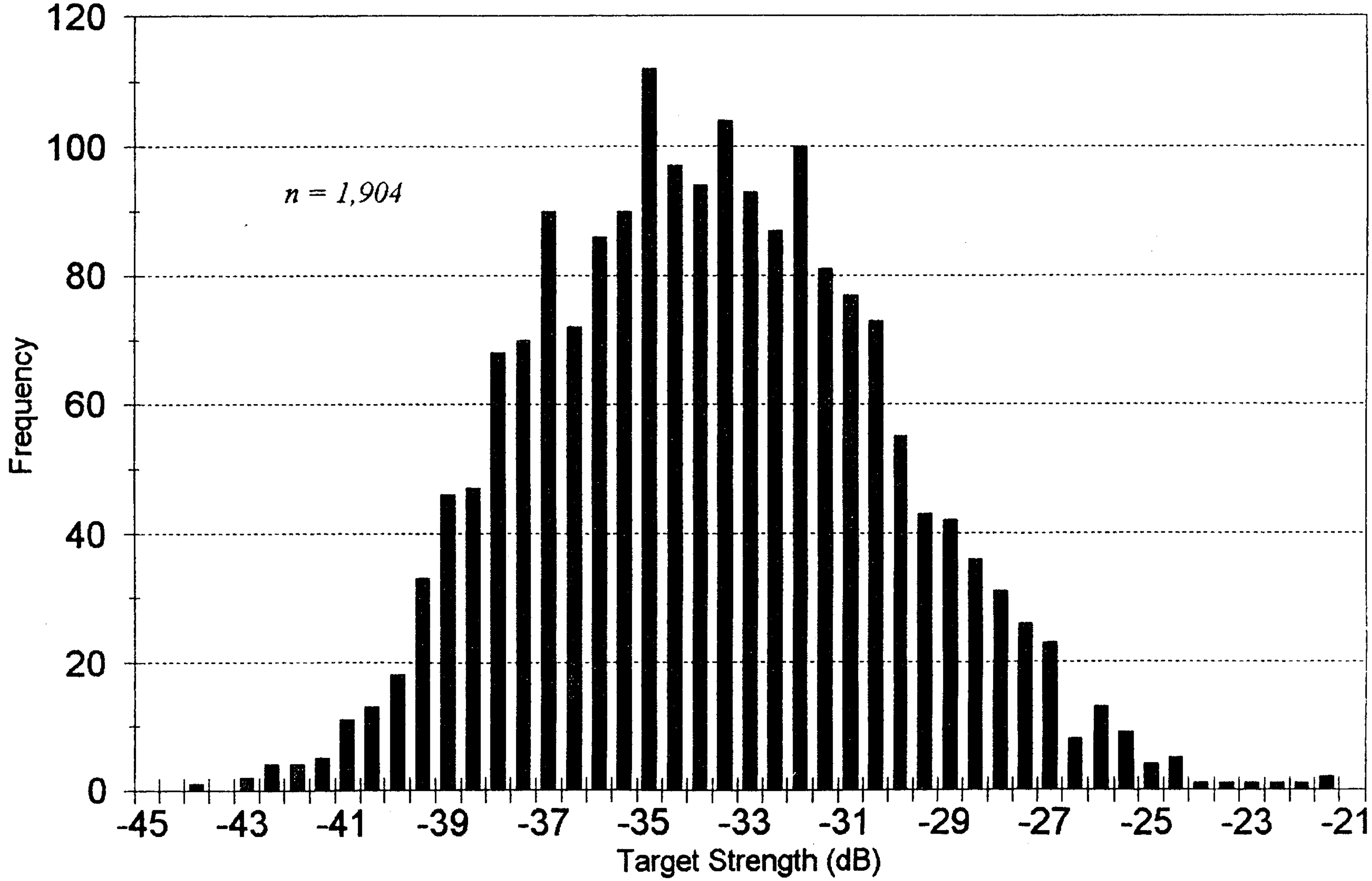


Figure 3. Target strength distribution of free-swimming fish acoustically sampled on the right bank of the Yukon River at Eagle, Alaska in September, 1992.

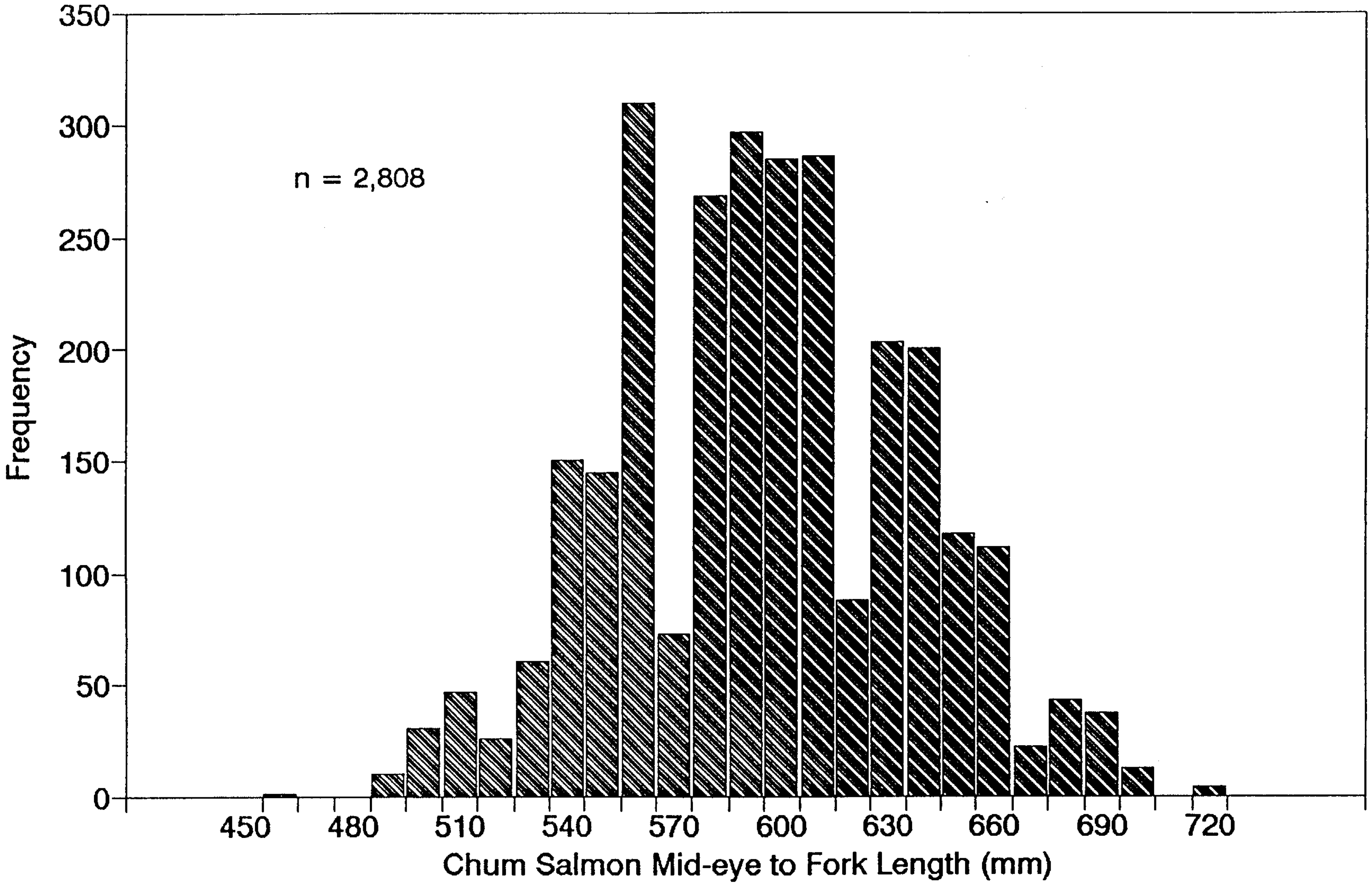


Figure 4. Length frequency distribution of Yukon River District 5 and District 6 chum salmon caught in commercial fishwheels and gill nets in 1992.

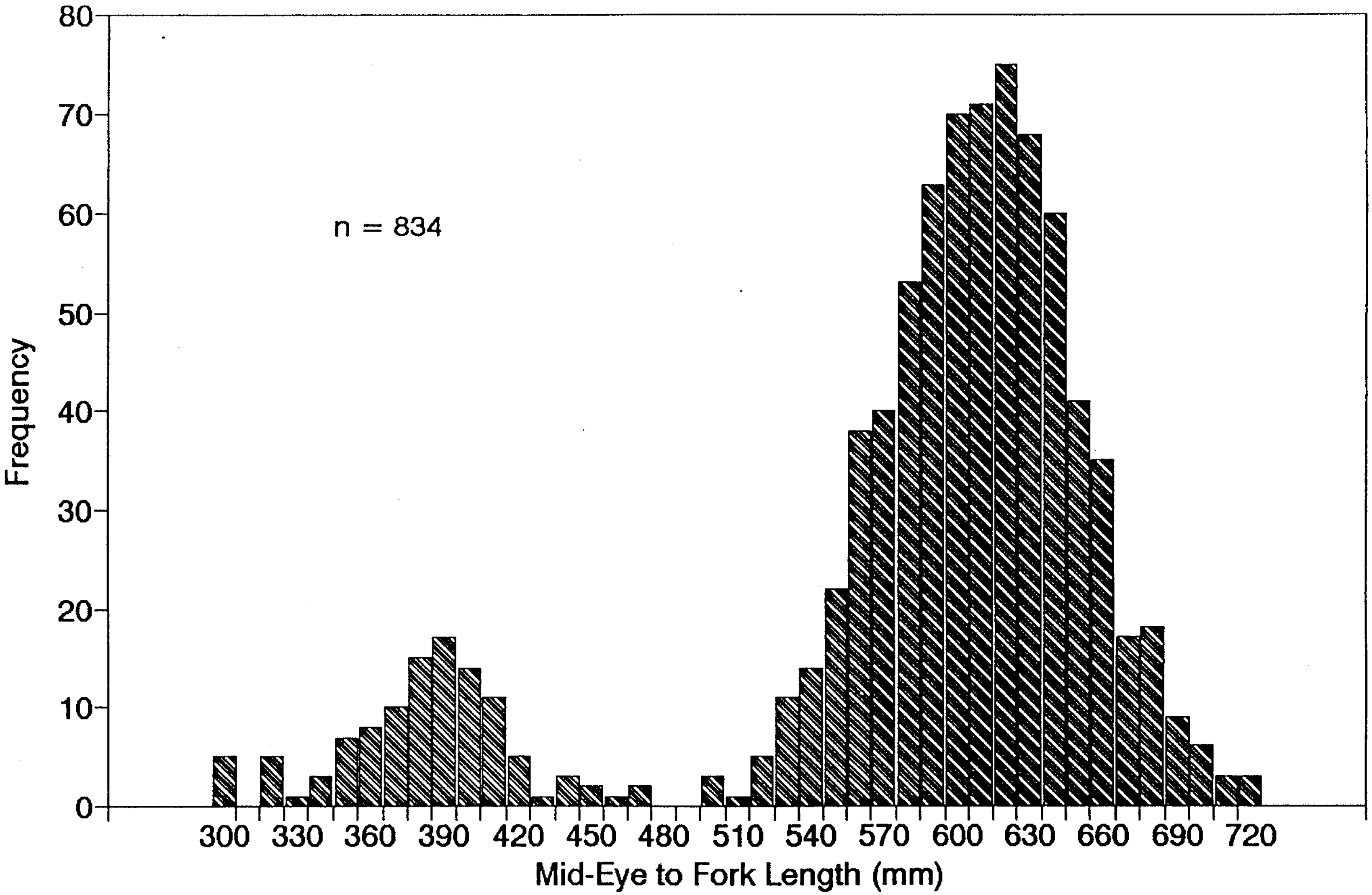


Figure 5. Length frequency distribution of all fish caught in sonar-related test fishing activities at Eagle, Alaska in September, 1992.

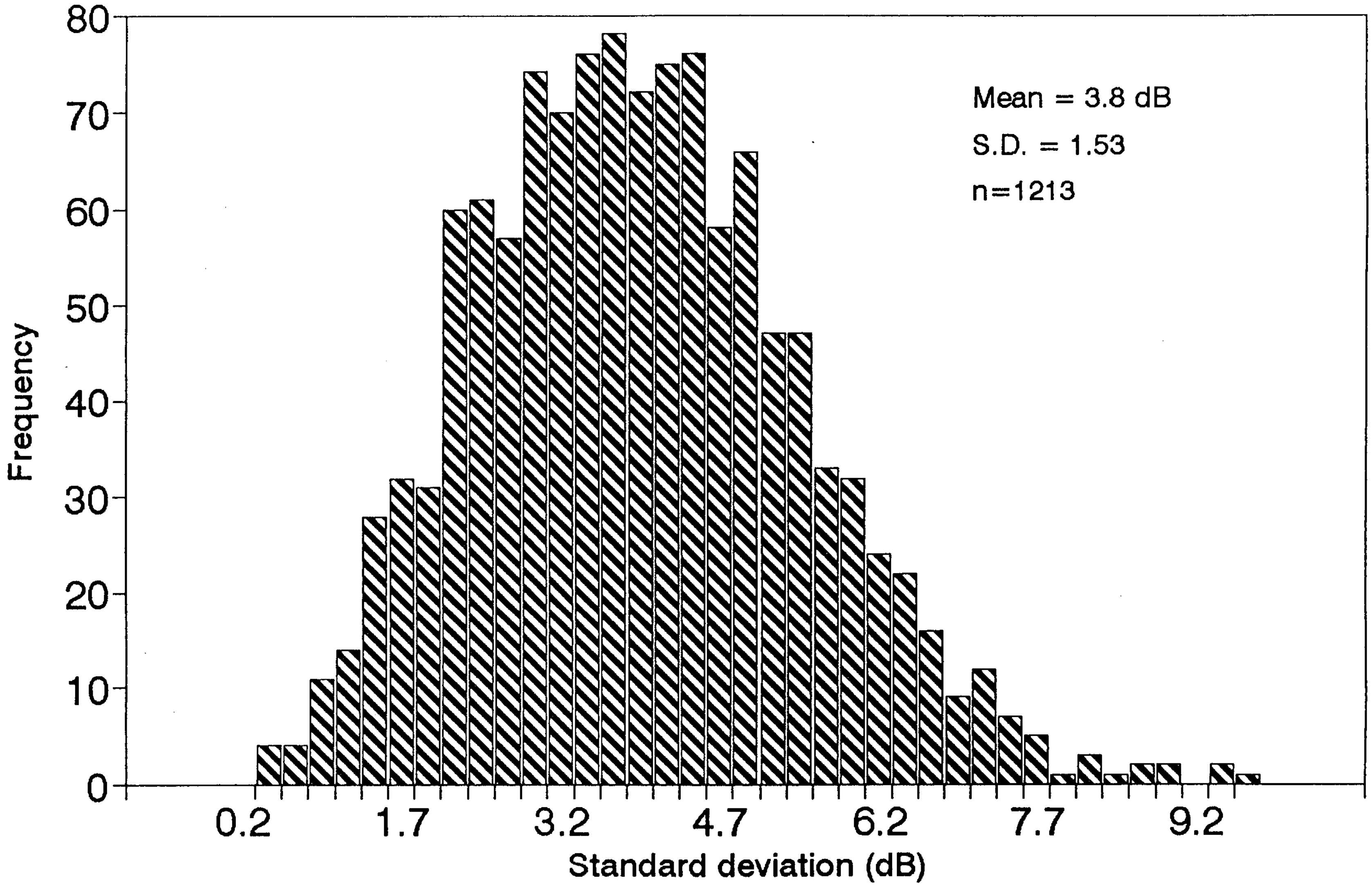


Figure 6. Distribution of standard deviations of within fish estimates of target strength of free swimming fish Yukon River at Eagle, Alaska, 16 September 1992.

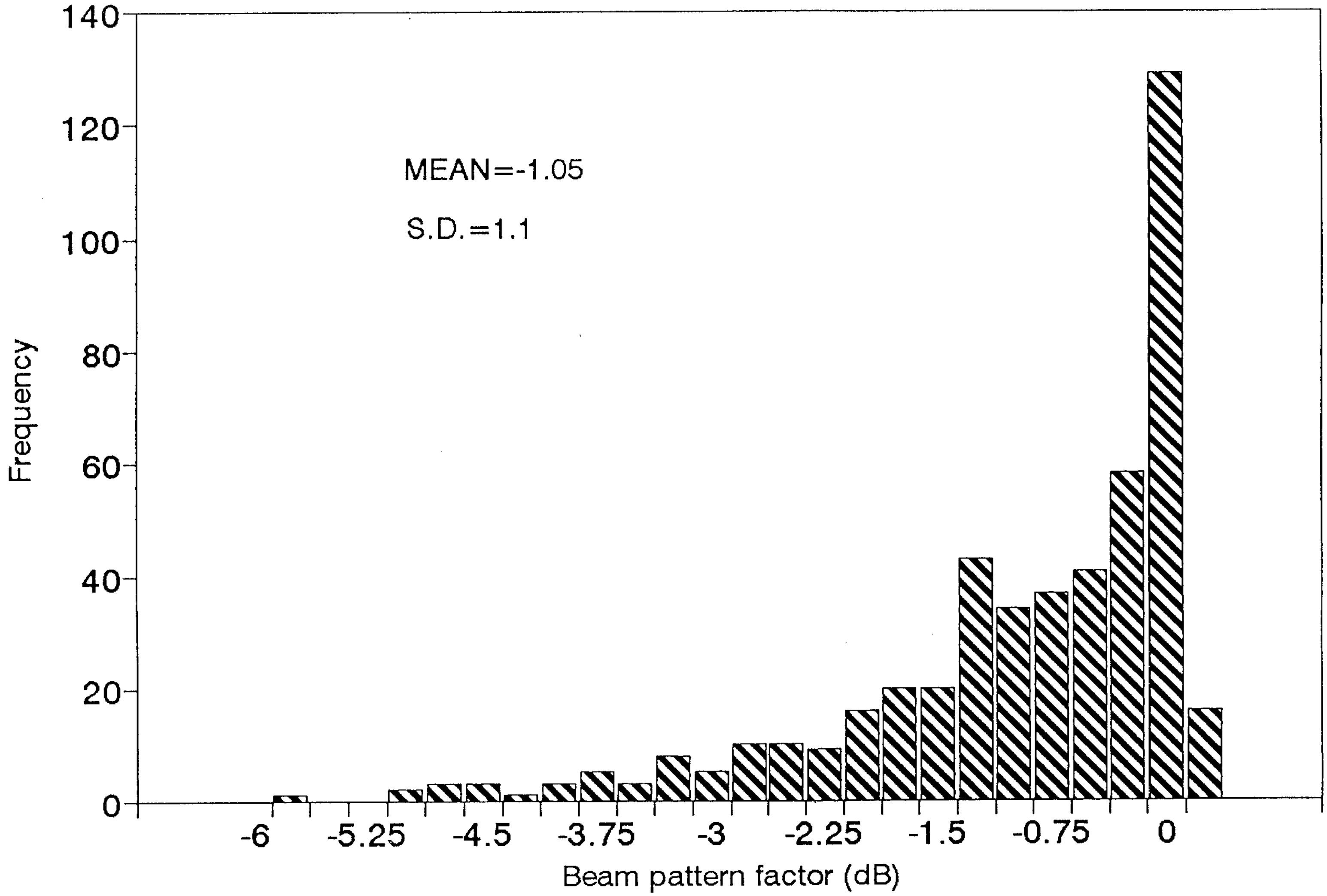
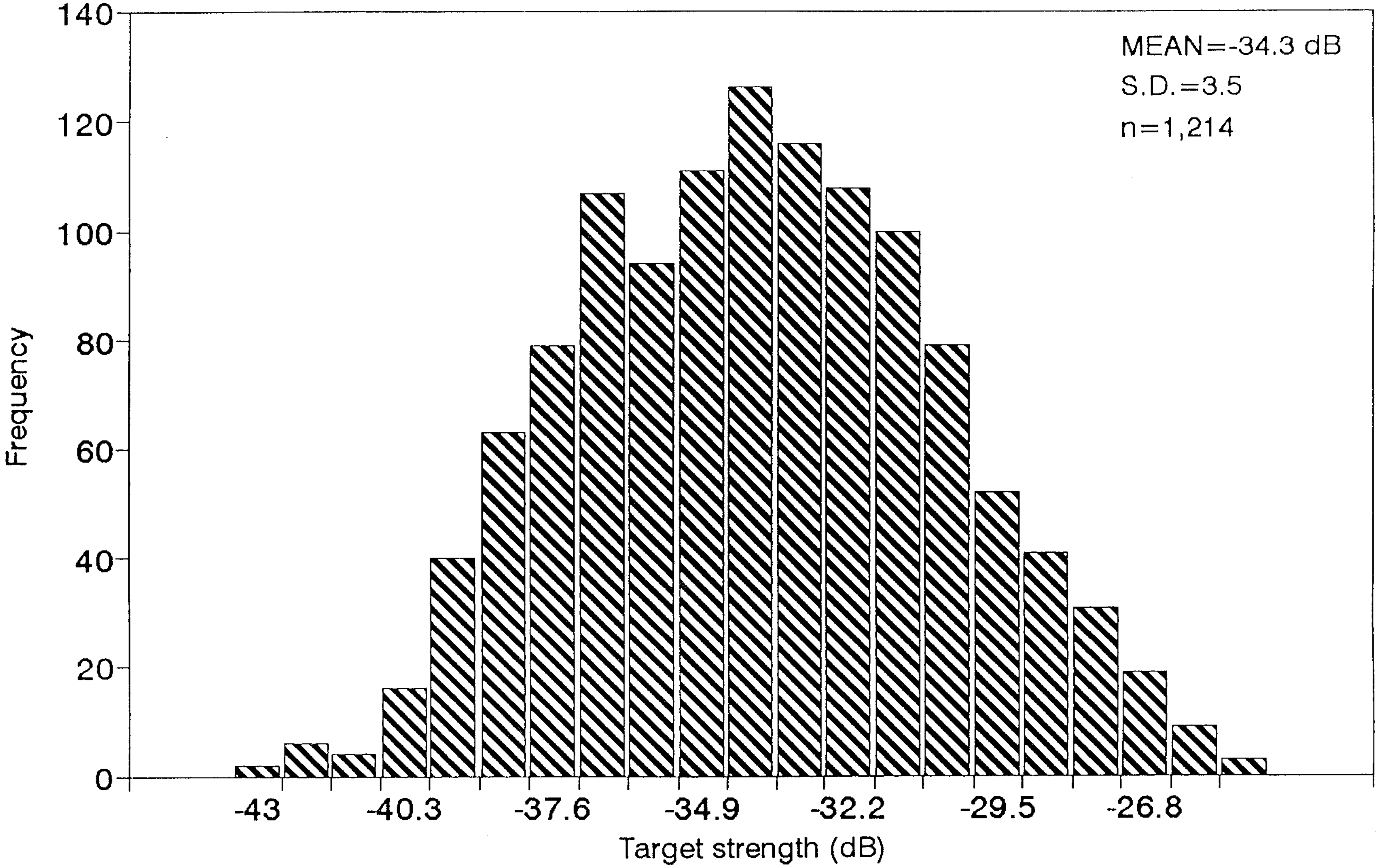
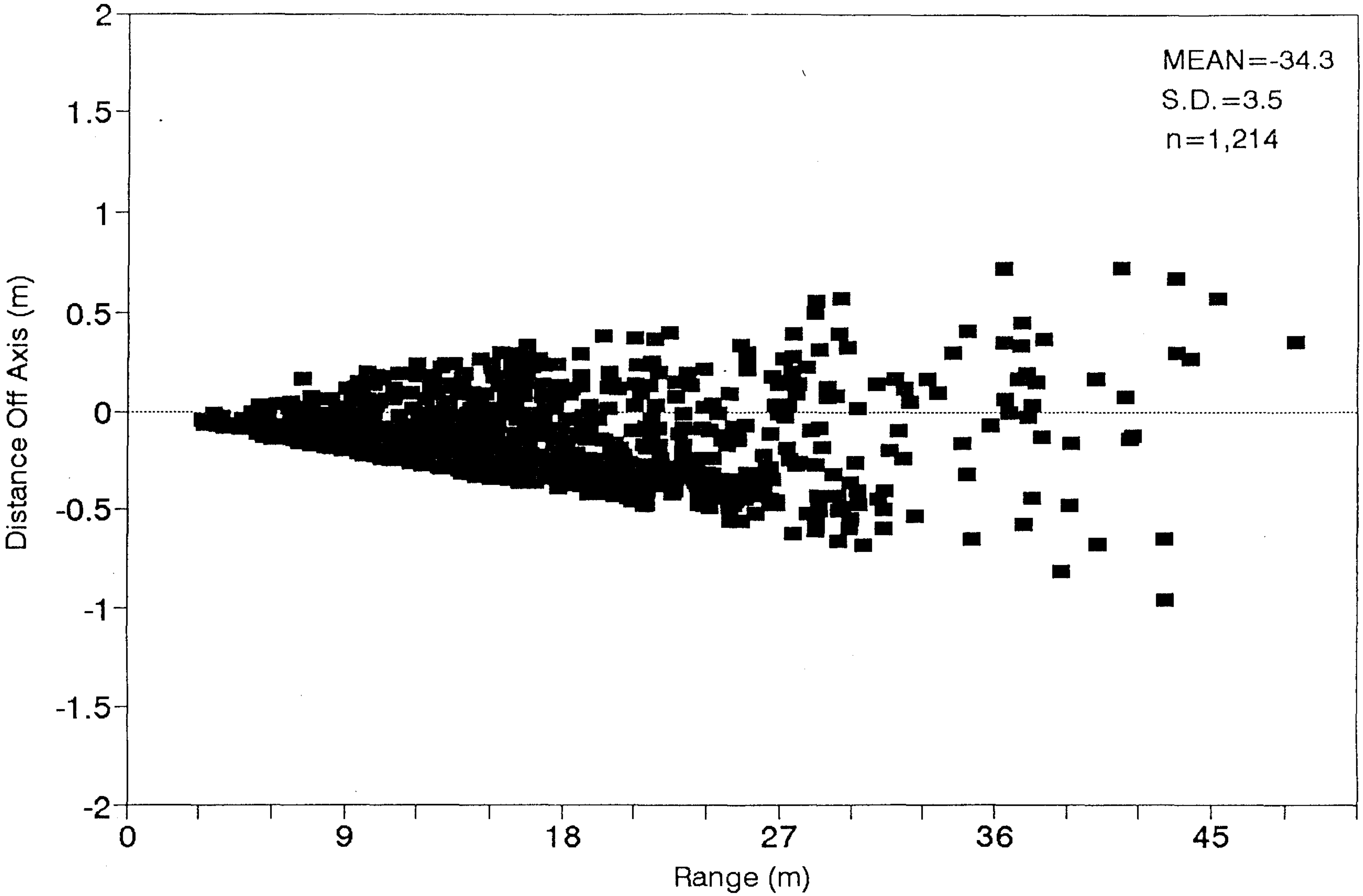


Figure 7. Histogram of beam pattern factors (dB) for a 38.1 mm stainless steel sphere sampled with split beam sonar in the Yukon River at Eagle,Alaska on 23 July 1992.

APPENDIX A

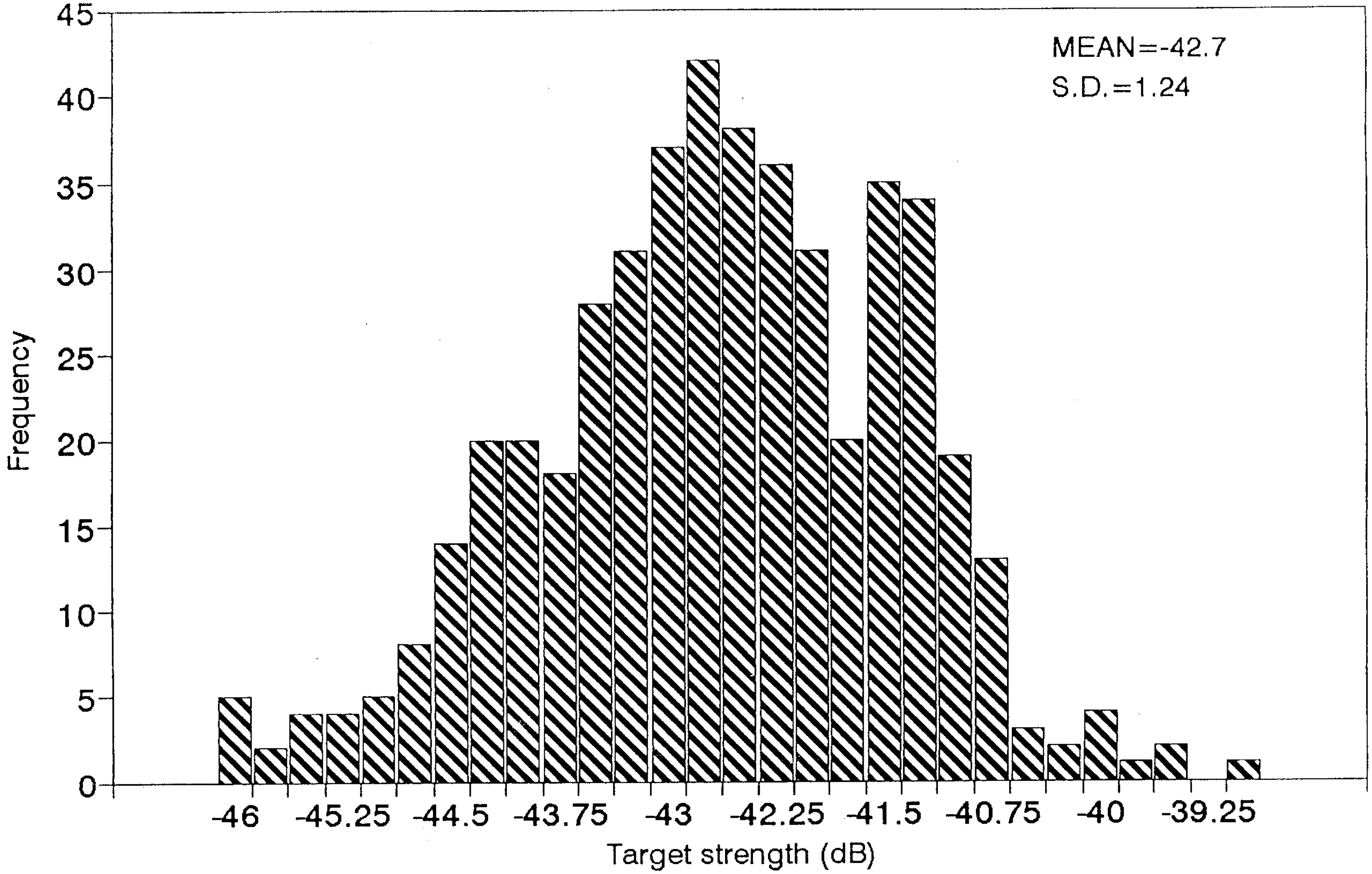


Appendix A.1 . Target strength (dB) distribution of fish ensonified on the right bank of the Yukon River at Eagle, Alaska on 16 September 1992.

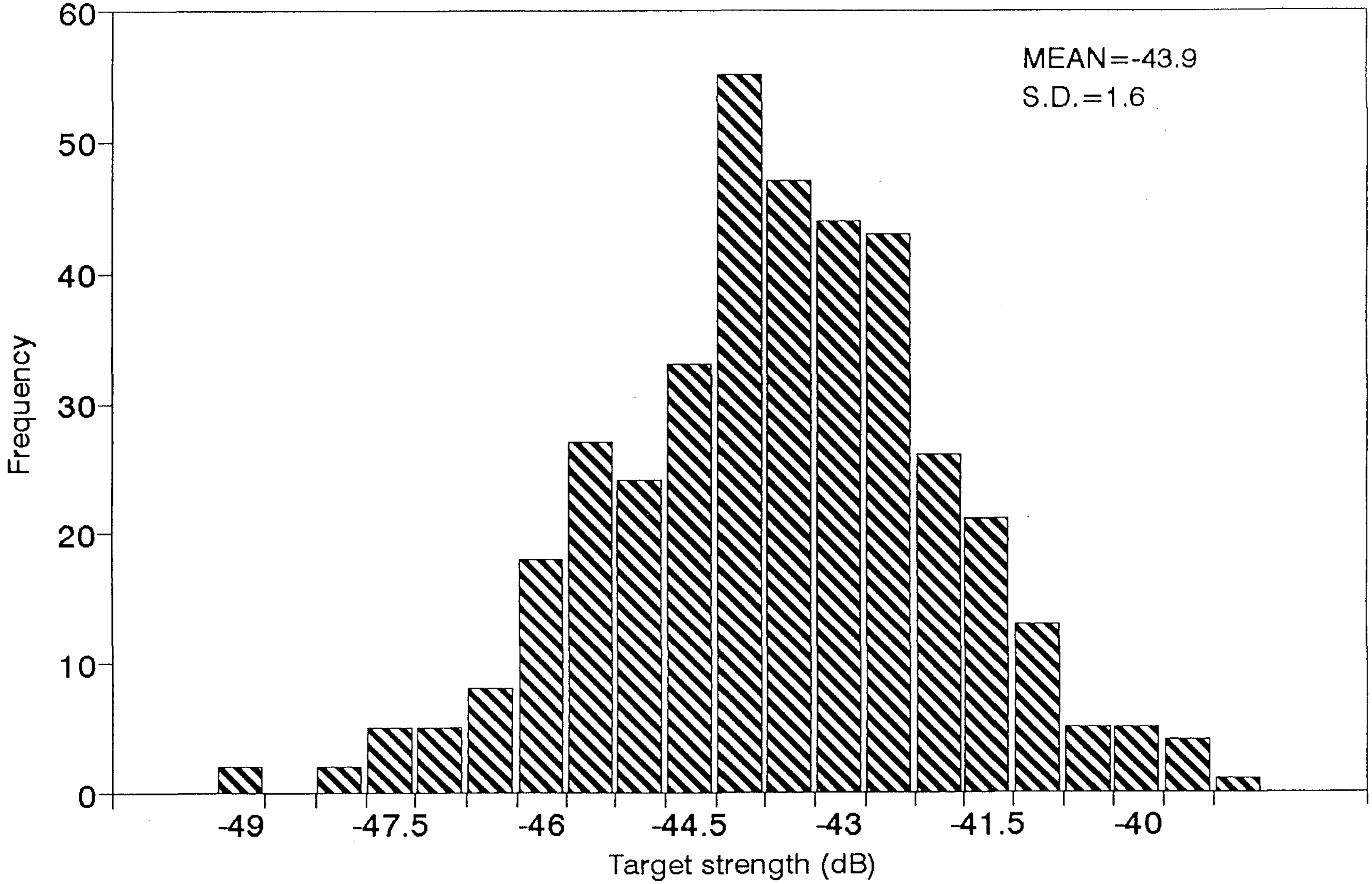


Appendix A.2 . Vertical and horizontal distribution of ensonified fish along the right bank of the Yukon River at Eagle, Alaska on 16 September 1992.

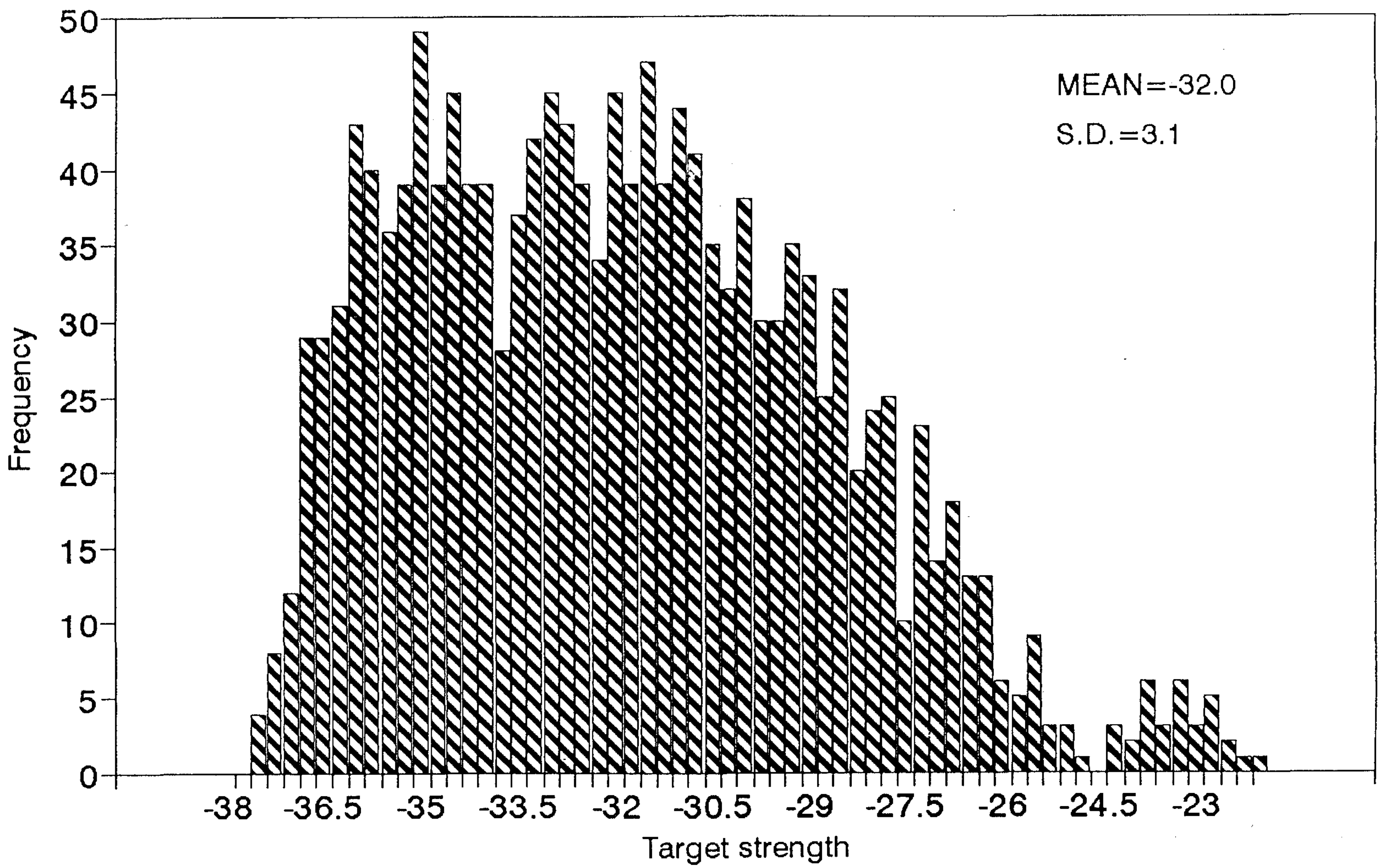
APPENDIX B



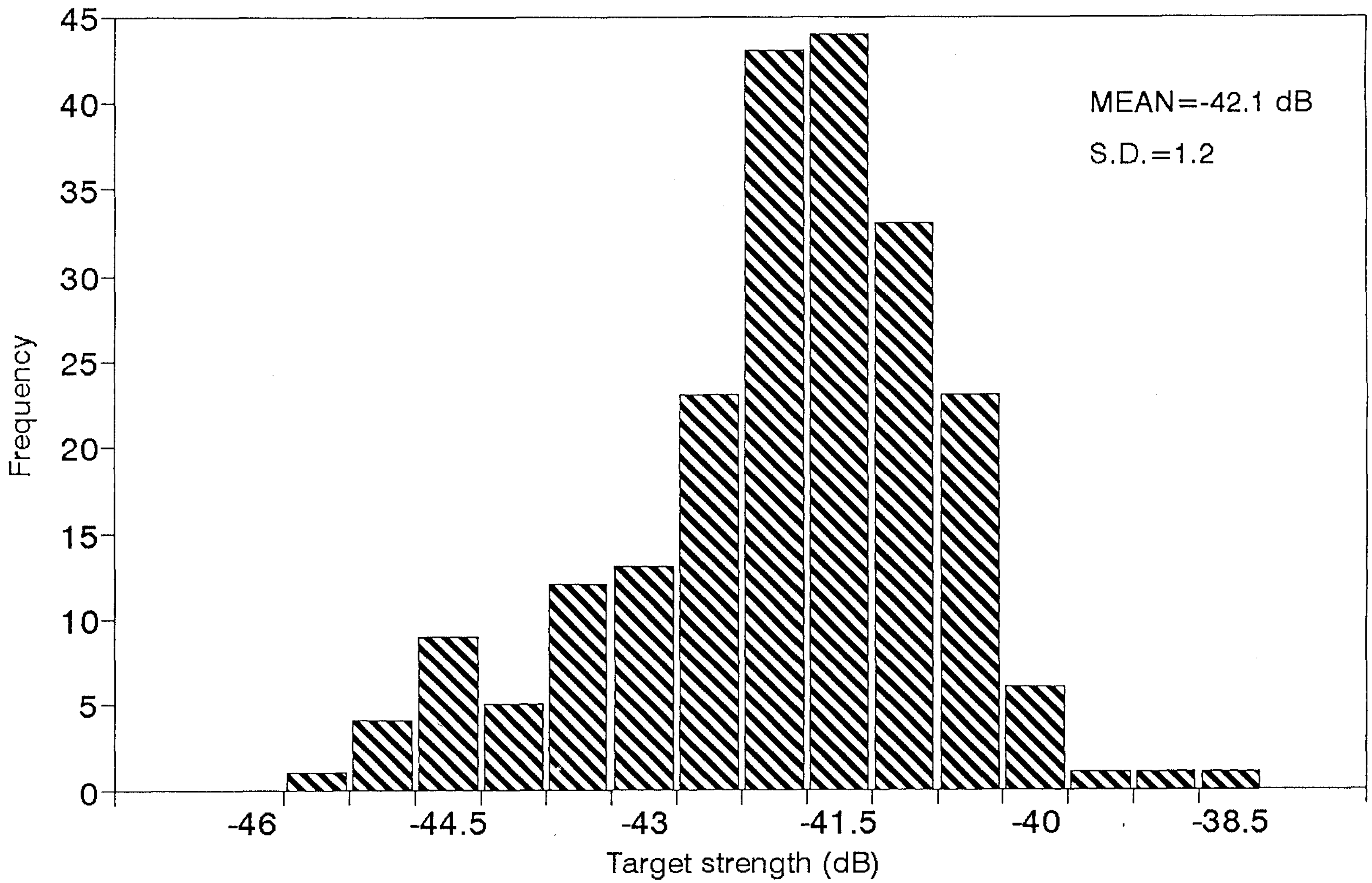
Appendix B.1. Target strength (dB) distribution of a 38.1 mm stainless steel sphere measured in situ using a split beam echo sounder in the Yukon River at Eagle, Alaska on 23 July 1992.



Appendix B.2. Target strength (dB) distribution of a ping pong ball measured in situ using a split beam echo sounder in the Yukon River at Eagle, Alaska on 23 July 1992.



Apendix B.3. Target strength (dB) distribution of an 89 mm (10 lb) lead sphere measured in situ using a split beam echo sounder in the Yukon River at Eagle, Alaska on 23 July 1992.



Appendix B.4. Target strength (dB) distribution of a 25.4 mm copper sphere measured in situ using a split beam echo sounder in the Yukon River at Eagle, Alaska on 23 July 1992.